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Watershed Management for Summer Flood Control in Utah

U. S. DEPARTMENT OF AGRICULTURE • FOREST SERVICE

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FOREWORD

Floods affect nine-tenths of the Nation's people. Preventing or reducing flood devastation is therefore a general public concern. As this publication shows, flood hazards are sometimes greatly increased by man's activities on mountain lands. Uses of watershed lands that damage their plant cover may demand an exorbitant price in destruction and suffering from the floods that follow. But if action is taken in time, it is often possible to remedy the poor conditions of plant cover and soil that needlessly expose a community to floods. The successful experiences of Utah communities in avoiding or correcting watershed abuses, as described here, will be of wide interest.

In your locality, don't wait until the damage is done. Find out the condition of your watershed. If it is in good condition, make certain it is kept so by wise care. If it shows signs of deterioration, begin at once to have it restored, and see that it gets continuous good management.

Lyle F. Watts

Chief, Forest Service

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COVER PHOTO.—Salt Lake City, like other communities in Utah, has reason for concern about the management of its watershed lands.

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Watershed Management For Summer Flood Control in Utah

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Contents

	Page
Introduction	1
Farmington-Centerville community imperiled by mud-rock floods	2
Unnatural floods a sequel to watershed abuse	6
Good watershed management prevented floods	13
Runoff controlled by watershed improvements	14
Improved watersheds withstood torrential rains	16
Runoff relations on reconditioned watersheds	19
Why continuous watershed management is necessary	20
Literature cited	23

Introduction

White men began to make permanent homes near the Great Salt Lake a hundred years ago. The first enterprise for irrigating farm land in Utah was launched on July 24, 1847. Since then, valley lands have become wealth-producing orchards and fields, towns and cities have sprung up, and industries have been established. All of this was made possible by water from the mountain streams. Among the uses to which the mountain lands were put for man's benefit was livestock grazing.

Year after year, Utah streams rose to sustained moderate heights in the spring during snow melt. They also rose to similar stages for brief periods following summer rains. Some streams, draining naturally barren or sparsely vegetated slopes, flooded frequently. Such floods were normal and expected. Many of the mountain streams, however, delivered storm flows usefully and safely; the plant and soil mantle on the watershed slopes was able to cushion, absorb, and slowly release water from both melted snow and summer downpours.

A radical change in stream behavior took place on many watersheds some years after the coming of white men. Instead of moderate rises in stream flow, great floods of debris-laden water burst upon the valley lands. Lives were lost, property was damaged, land was ruined, and communities were disrupted.

In 1923, these debris floods became especially serious in the Farmington-Centerville area in northern Utah. They were repeated time and again. Soon

it was clear that if such floods continued and grew worse, the valley communities would be ruined. The alarmed people asked: Can these floods be stopped? What causes them?

The wrath of the floods was visited on this valley because the watershed had been abused. Overgrazing and fire on the mountainsides had so damaged the land that it could no longer hold torrential rainfall. Surface runoff raced down the slopes carrying soil that had been stable for thousands of years. Collecting in channels, the muddy waters gouged out the beds and banks of streams as they roared on their way carrying great masses of eroded material to the valley lands below.

Could the floods be stopped? The people of the valley decided to try. Under the Civilian Conservation Corps program the slopes above the valley were replanted to grass. Contour ditches were made to catch and hold the water until the vegetation had a chance to get a foothold and take over control of the water. Livestock and fire were kept out.

The healing of the flood-scarred watershed slopes by trenching and the reestablishment of a plant cover has progressed far enough that the land has been able to absorb and hold rainfall and to furnish water to the streams usefully and safety. But the people in the locality paid a heavy price for the floods and the repair work. Wise management could have prevented the hardship and expense. An example of such management is to be found nearby—in Centerville Canyon. There livestock was wisely handled and the watershed protected. No floods took place.

The lesson is plain. Abuse of watersheds must stop or summer floods in Utah will increase. The losses will mount, and so will the cost of eventual control. Careful tending of the watersheds over the years will keep the costs low and the resources in condition for use indefinitely.

This publication briefly reports the evidence of the way in which destructive mud-rock flows were caused in parts of Davis County, Utah. It also describes the watershed management practices and improvement measures by which these floods were controlled. Communities in Utah and elsewhere where floods are possible can profitably study these examples of effective watershed restoration and watershed management.

Farmington-Centerville Community Imperiled by Mud-Rock Floods

Farmington and Centerville, situated at the base of the Wasatch Mountains along the eastern shore of Great Salt Lake, are two of the earliest settlements in Utah (fig. 1). These communities prospered as irrigation was extended over the 6,000 acres of productive land between them. Water for the towns and the farms came from several small streams draining some 25 square miles of forest- and brush-covered mountains (fig. 2). These streams, the people had learned, could be depended upon to supply their water.

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Figure 1.—**The town of Centerville shown here, like all the intensively developed Farmington-Centerville area, lies close to the base of the steep Wasatch Mountains.**

Every spring, sustained rises in stream flow occurred as the snow receded up the slopes and finally disappeared. Occasionally, violent summer storms in the mountains brought freshets that caused temporary inconvenience and minor damage. Fords were closed, some gravel was rolled into diversion canals, and

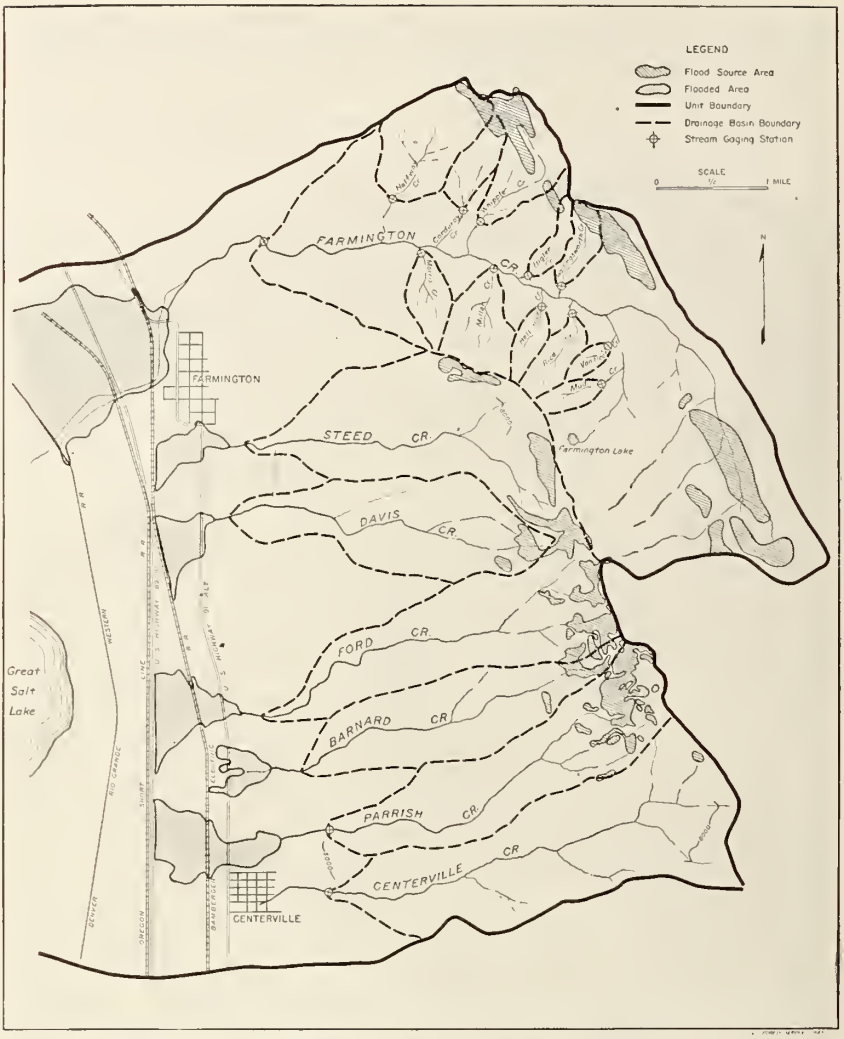

Figure 2.—Seven perennial streams drain the mountain land and supply water for domestic, industrial, and irrigation purposes.

the water remained cloudy for a short time. None of these storm flows, however, was large enough to prevent use of the water or to interfere with normal use of the land, even up to the mouths of the steep canyons.

The useful character of summer stream flow was abruptly changed in 1923, when, in midsummer, five of the small streams watering the area produced devastating debris-laden floods (*13*).[1] Again, 7 years later, the same kind of mud flows came from these streams while a sixth disgorged the most devastating flood of all. Some of these mountain streams spewed out three more flows in the same summer.

[1] Italic numbers in parentheses refer to Literature Cited, p. 23.

These mud-rock floods, bursting from the canyons, wrought havoc (fig. 3). Six people lost their lives during the 1923 floods. Homes were crushed or filled with debris. Orchards and crops were destroyed. Highways and railroads were blocked. Irrigation diversion works and canals were washed out or buried. Farm lands were covered with mud, gravel, and boulders—some too deeply to be reclaimed.

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Figure 3.—Typical scenes of mud-rock flood damage near Ford Creek in 1923: *A*, Exhuming automobile from mud following flood in Ford Canyon; *B*, one of 7 houses destroyed in the Farmington-Centerville area in an 8-year period.

The floods did more than physical damage to the land and other property. For a time they caused severe economic shock and paralysis in the community. Interest and mortgages remained unpaid. Banks refused to extend credit. Many people wanted to sell and get out, but no one would buy property in the flood zone. Real estate brokers refused even to list property for sale. Damages during the 1923–30 period varied between basins but totaled about $1,000,000 (table 1), including losses in property values. This was more than one-fifth of the total assessed value of all property in the area.

TABLE 1.—*Relation of flood damage to the area drained, and damage per acre of flood-producing drainage basins, Farmington-Centerville area, 1923–30*

Drainage basin	Watershed area	Total flood damages	Average damage per acre of watershed land
	Acres	*Dollars*	*Dollars*
Farmington	6,322	226,235	36
Steed	1,767	80,463	46
Davis	1,005	118,682	118
Ford	1,507	278,422	185
Barnard	889	13,290	15
Parrish	1,378	336,497	244
Total or average	12,868	1,053,589	83

The destructive behavior of these floods aroused public concern. It was felt that the community could not withstand much more of this, and that the floods had to be stopped. The Governor of Utah appointed a commission to study the flood situation (*6*).

Certain basic questions had to be answered correctly if a sound program of action was to be assured. Were these mud-rock flows entirely new in this locality or had they been occurring periodically over the ages? What caused the floods? Could such floods be prevented? If so, how?

Unnatural Floods a Sequel to Watershed Abuse

Geologic evidence revealed that the mud-rock floods of 1923 and 1930 were radical departures from the normal runoff characteristics of the canyons (*5*). In depth of cutting, in quantity of material and in size of boulders carried, these floods far exceeded any others that have taken place since the predecessor of the Great Salt Lake—the vast, prehistoric Lake Bonneville—receded from this area many thousands of years ago (figs. 4 and 5). It was clear, therefore, that something unusual had caused the floods.

Rainfall records throughout the State did not show that there had been any major increase in the size or character of the summer storms. Soil moisture

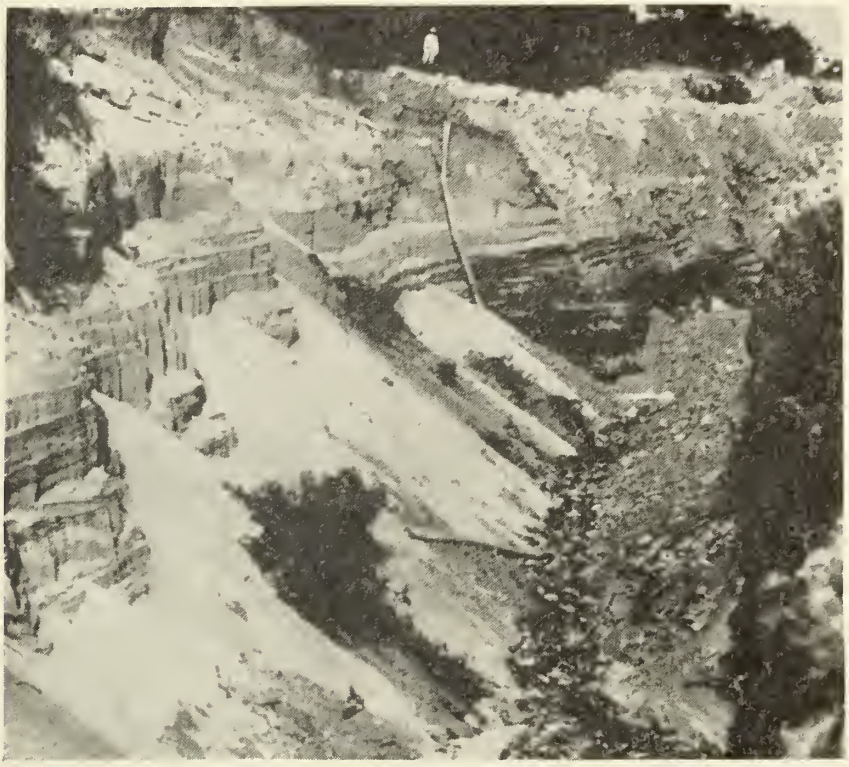

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Figure 4.—**The floods of 1923 and 1930, in places, cut to a new depth of 40 feet in previously undisturbed sands and gravels laid down in the water of Lake Bonneville many thousands of years ago.**

conditions confirmed this locally. Watershed soils in these mountains will hold from 2 to 3 inches of water per foot of depth (*10, 11*). After the floods, it was found that in favorable places water had penetrated the soil to depths of only 6 to 10 inches. This would indicate that less than 2 inches of rain had fallen. Summer rains of such magnitude in the mountains are not unusual. Therefore, the only reasonable explanation for the unprecedented floods must have been a radical change in the ability of the watershed lands to restrain runoff (*1, 2*).

Investigators found that the great bulk of the flood waters originated on areas near the mountain top where the plant and litter cover had been destroyed or reduced and the soil eroded and compacted. Here, on scattered areas of from less than one to only a few acres in size, there were freshly cut rills and gullies leading directly into the headwater channels (fig. 6). All together, depleted and eroded barren areas covered less than 10 percent of the total area of the several catchment basins (table 2). But the large number and deepness of the gullies showed that much water had been funneled quickly to the channels to start the mud-rock floods.

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Figure 5.—This mud-rock flood from Parrish drainage, on July 10, 1930, laid mud, rocks, and boulders on top of the deep, rich soil which had previously developed from fine silts and sands deposited in ancient Lake Bonneville. The new, coarse material clearly indicated that the floods were a radical departure from normal discharges.

TABLE 2.—*Relation of flood-source area to total watershed area of six flooding canyons*

Canyon	Watershed area	Flood source	
		Area	Proportion of watershed area
	Acres	*Acres*	*Percent*
Farmington	6,322	715	11.3
Steed	1,767	175	9.9
Davis	1,005	75	7.5
Ford	1,507	125	8.3
Barnard	889	50	5.6
Parrish	1,378	175	12.7
Total or average	12,868	1,315	9.2

From the ends of the headwater gully systems, deep gorges were freshly excavated the full length of the flooded canyons. The canyon fill, which had lain undisturbed for centuries (fig. 7), was washed out to depths up to 70 feet. Bedrock was exposed in long stretches of the channels. No such gorges entered the channels from the lower, better vegetated slopes of the watershed.

That the impaired land near the top of the mountain was the real flood source was proved by the lack of disturbance in the surrounding and intermingled well-vegetated areas. On the latter, there were no gullies, the litter cover on the ground had not been displaced, and the minor vegetation was standing erect. These signs were indisputable proof that the vegetated lands had not contributed significantly to the flood runoff.

Had rain fallen only on the interspersed, depleted areas? Even cloudburst type rains—though commonly localized—do not fall that way. Soil moisture again told the story. Numerous examinations of the soil on both flood-source and adjacent vegetated areas were made immediately after the 1930 floods. Moisture was found in both kinds of sites. However, in the nearly barren areas, rainfall had penetrated to a depth of only 1 or 2 inches, whereas in the more densely covered areas it had gone down to a depth of 6 to 10 inches. On both sites, the soil was dry for several feet below these depths. Clearly, the floods started because not enough of the rainfall could get into the soil mantle on the depleted areas.

This inadequate capacity of the flood-source areas to restrain runoff was unnatural. It was due to a change in the character of the soil. This was brought

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Figure 6.—Deep drainage channels divided near the mountain crest into freshly cut gully streams that quickly concentrated raindrops and funneled them with great force down the steep slopes.

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Figure 7.—Cut by only a few rainstorm runoffs, this gully in the Ford drainage area near the mountain crest indicates a complete reversal of age-old accumulation processes. The deep, fine alluvium in the ancient channel represents hundreds of years of slow accumulation.

about by long-continued overgrazing by domestic livestock, and unwise burning. The signs of misuse and abuse were plainly visible.

Dead and dying plants, perched on remnants of a once fertile soil, dotted the flood-source areas. All the shrubs were closely hedged, displaying the cumulative effects of past heavy grazing. Some were blackened by fire. Palatable grasses were absent. There was no plant litter on the ground. The eroded soil surface was hard-packed.

The landowners acknowledged that the headwater areas had been heavily grazed for many years. Some even admitted having set fires in previous years to kill out the dense brush in the hope of improving the forage. This burning, followed by overgrazing, speeded the deterioration.

These abuses had done more than deplete the forage. They had reduced the capability of the lands to cope with high-intensity rainfall.

The observed differences in the capacity of bared and covered areas to prevent runoff and erosion have been verified by measurements on experimental plots in the headwaters of Parrish Canyon (fig. 8). During intense rains in 1936, plots representative of the deteriorated flood-source areas on the average yielded from about 60 to 160 times more runoff than those representative of more adequately covered non-flood-source conditions. Soil losses from the deteriorated plots ranged from 83 to 181 cubic feet per acre during individual storms whereas no measurable quantity of soil was lost from the non-flood-source plots (table 3).

TABLE 3.—*Rainfall, runoff, and soil losses on Parrish Creek plots,*[1] *1936 and 1945*

Date	Rainfall	Average runoff		Average soil loss per acre from flood source [2]
		Nonflood source	Flood source	
	Inches	*Percent*	*Percent*	*Cubic feet*
July 10, 1936	1.14	0.7	42.8	181.5
July 16, 1936	.89	.4	43.4	153.6
July 27–28, 1936	1.21	.2	33.0	83.2
Aug. 18–20, 1945	[3] 3.09	.5	24.3	92.8

[1] Includes four $\frac{1}{10}$-acre plots on non-flood-source areas (aspen plots) and twelve $\frac{1}{40}$-acre plots on flood-source areas (both weed and brush plots).

[2] No measurable quantity of soil has been lost from non-flood-source plots since their establishment in 1934.

[3] Includes 1.06 inches during evening storm of August 19.

On August 18–20, 1945, after 9 years of protection from fire and grazing, the plots were subjected to four intense rains that totaled 3.09 inches. One of these rains amounted to 1.06 inches and attained a maximum 5-minute rate that was 35 percent greater than the maximum rate attained in the 1936 storms. Notwithstanding the large volume and high intensity of these rainstorms, the non-flood-source plots absorbed all but 0.5 percent of the rainfall, and again lost no soil. The plant cover had increased somewhat on the flood-source plots since 1936. This improvement, however, was not sufficient to cope with the rainfall, 24 percent of which ran off as overland flow carrying with it the equivalent of 93 cubic feet of soil per acre.

These experimental plots provided further evidence of the effectiveness of plant and litter cover in controlling surface runoff and erosion during a moderately intense rainfall of 0.73 inch on August 10, 1947. Prior to this storm all of the plant and litter cover had been removed from one of four non-flood-source aspen

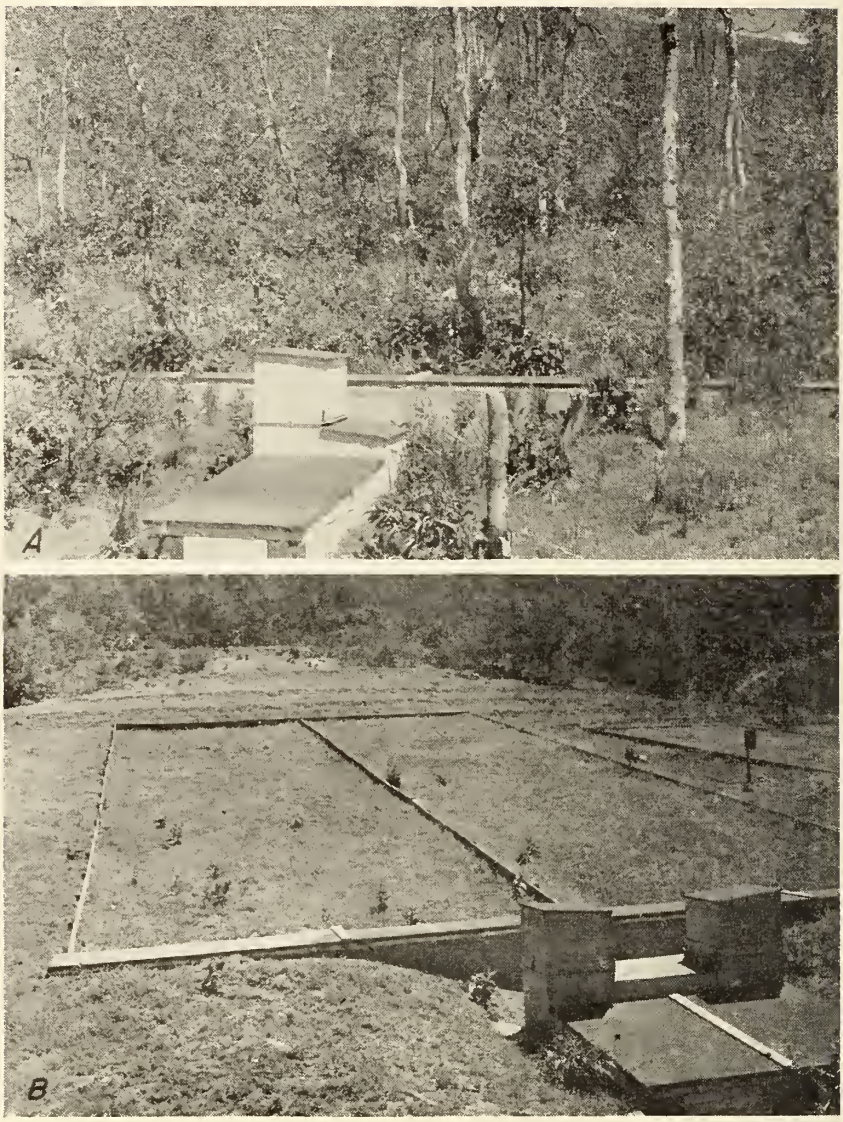

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Figure 8.—Parrish Creek surface runoff plots: *A,* non-flood-source aspen area; *B,* a typical, weedy, flood-source area.

plots. Two of six weedy, flood-source plots were also denuded so as to recreate flood-source conditions essentially similar to those that existed at the time of the floods in 1930. Two of the other four weedy plots were mulched and seeded to grass and on the remaining two plots, a young aspen and grass cover which had invaded the areas was allowed to remain unchanged. The four improved weedy flood-source plots absorbed all but 6.5 percent of the rainfall and lost no soil.

The freshly bared flood-source plots, on the other hand, yielded 62 percent of the rainfall as runoff and lost the equivalent of 60 cubic feet of soil per acre. The bared aspen plot, which before treatment had yielded less than 1 percent runoff and no soil, produced nearly 25 percent runoff and lost 140 cubic feet of soil per acre. The untreated aspen plots behaved as before, yielding less than 1 percent runoff and no soil.

These runoff and erosion plot records are not unusual. Results of tests on 97 sites, typical of a variety of residual soils and plant-cover conditions on mountain range in Utah, show comparable effects of plant cover on runoff. Where the plant and litter material was approximately normal for the site, runoff averaged about 5 percent of the rainfall applied. On deteriorated parts of the same areas, runoff increased as the density of the protective mantle decreased—nearly bare areas yielding from 20 to 80 percent runoff. Essentially similar plant-cover and runoff relations were found to prevail on grazed watersheds in central Utah (*12, 15*), on a variety of range types in southwestern Idaho (*9*), and in numerous other places in the United States (*14*).

These observations and measurements show how poor watershed management brought about in the flooded canyons was found in Centerville Canyon. less litter was added to the soil, less rainfall was able to get into the mantle; and as summer storm followed summer storm over the years, the mantle became still less receptive. A small amount of rainfall produced runoff. Eventually, enough surface runoff was generated to start the mud-rock floods. Then, after gullies had been carved in the slopes and channels, water could rush down faster and only minor storms were needed to cause additional floods.

Good Watershed Management Prevented Floods

A striking contrast to the unhappy consequences that poor watershed management brought about in the flooded canyons was found in Centerville Canyon. Years ago the people of Centerville acquired part of the land in the upper portion of this drainage and arranged with the owners of the remainder of the land for conservative grazing use in the entire watershed. As a consequence, the plant cover and soil mantle has been effective in handling summer rains.

Good management in this watershed has paid dividends. Centerville Canyon produced no mud-rock floods in 1923 or 1930, nor has it produced any such flood in recent geologic time. Centerville Creek rose a foot or two and remained at that level for several hours after the more violent mud-rock flows in the adjacent canyons had passed, but the moderate storm-flow discharges continued to be entirely usable.

Centerville Canyon unquestionably received heavy rains. Very small denuded patches on its slopes were gullied in the same manner and to the same degree as the more extensively denuded flood-source areas of the neighboring catchment basins. However, surface runoff and the eroded material on these patches never reached the channel but were absorbed by the soil on the densely

covered areas surrounding the barren spots. What is more, measured rains of record-breaking intensities have since occurred in this basin but have not produced floods.

The nonflooding behavior of this canyon further demonstrated the importance of undamaged plant cover in controlling summer rainfall runoff.

The requirements for preventing mud-rock floods in the other canyons became clear: First, the causes of plant and soil deterioration had to be removed, and second, infiltration capacity on the flood-source areas had to be increased. Accomplishment of these two objectives, it was believed, would reestablish the delicately balanced relation between slope, vegetation, soil, and rainfall which had existed on the watersheds in the Farmington-Centerville area for thousands of years before settlement. The process would doubtless be slow but once the balance was reestablished, the same degree of summer storm runoff control originally provided by the plant and soil mantle would be attained.

Runoff Controlled by Watershed Improvements

Local people cooperated with Federal and State agencies to accomplish the flood-control job. Some debris basins and floodways were installed for temporary protection, but the main effort was concentrated on stopping runoff at its source.

The first essential to watershed rehabilitation—removal of the causes of soil- and plant-cover deterioration—required control of grazing and fire. This was made easier to accomplish by placing the lands in public ownership. Key tracts were acquired by local people. Additional lands were purchased and added to the Wasatch National Forest. Gradually, as land passed from private to public ownership, grazing was eliminated from the flood-source areas and fire protection was intensified.

The second essential, stabilizing soil and restoring the vegetation on flood-source areas, was carried out by Civilian Conservation Corps workers. They constructed contour trenches on the flood-source areas (*4*), and seeded the trenched and adjoining depleted areas with perennial grasses.

These contour trenches were installed on about 1,100 acres of headwater slopes. They were built wherever it was evident that natural or artificial revegetation could not, in a reasonable period, restore effective waterflow retardation or prevent erosion. Beginning on the upper slopes of such areas, trenches were installed at intervals of about 25 feet, each large enough to hold 1.50 inches of runoff. The trenches were to serve several purposes: (1) To break up the established gully system; (2) to impound rain and thereby keep storm runoff out of channels; and (3) to create favorable soil-moisture conditions for the reestablishment of a plant cover comparable to that which existed before depletion.

Bulldozer blades roughed out the trenches. Horses and plows were used, however, on very rocky areas and on slopes in excess of 50 percent. Hand shovels were required to finish the trenches to precise zero grades and to install small cross dams at intervals of 20 to 40 feet (fig. 9).

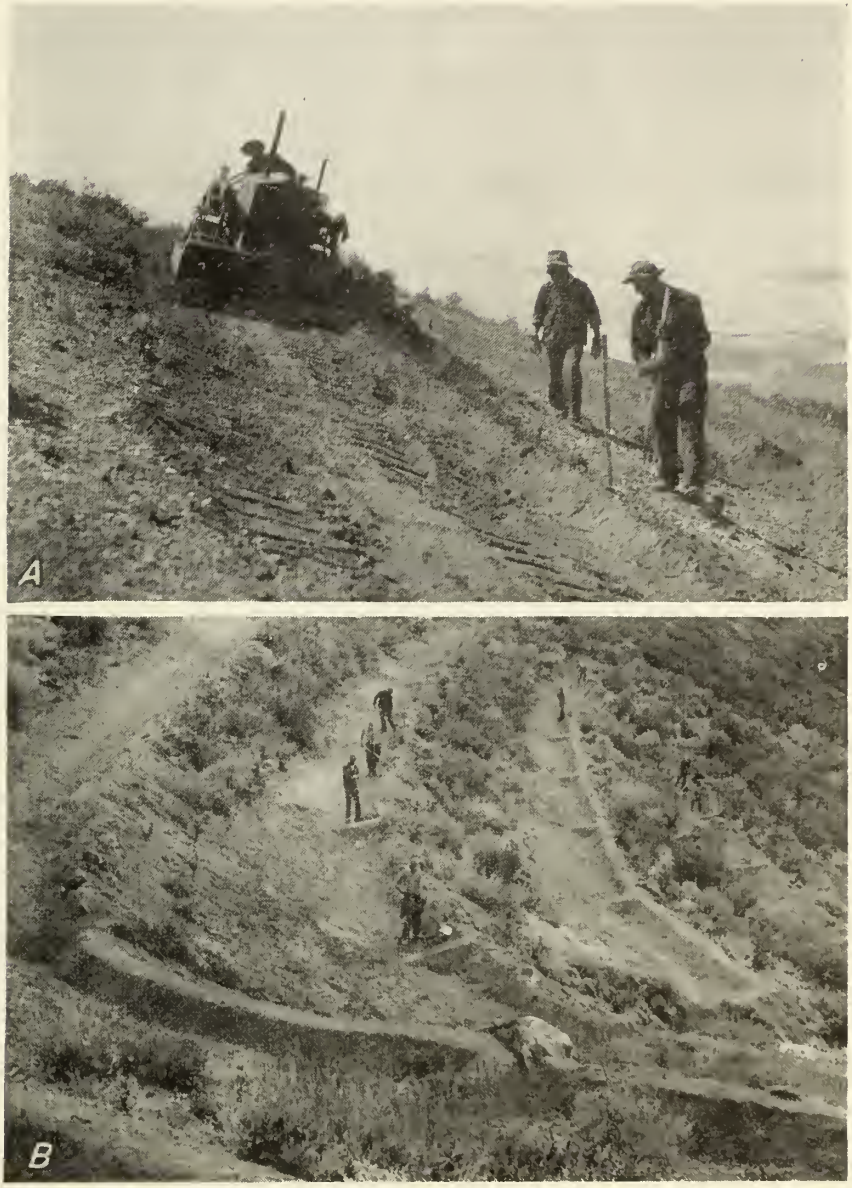

Figure 9.—A, Roughing out contour trench with bulldozer; *B,* Finished contour trenches on a flood-source area in Ford Canyon. The zero grade trenches are interrupted by cross dams at intervals of 20 to 40 feet, thus making a large number of storage units.

As a part of the finishing process, all contour-trenched areas, and other depleted areas, were sown with a mixture of seeds of five perennial grasses, including smooth brome, mountain brome, Kentucky blue, slender wheat, and English

rye. The seeds were broadcast on the loose soil and raked in. In addition, small, isolated, depleted areas, about 200 acres in extent and on which trenching was not done, were also seeded with these grasses to hasten their recovery. Of the 1,300 acres treated, 800 in the Parrish, Barnard, Ford, Davis, and Steed drainages received treatment of sufficiently high standard and degree of completeness to be set aside as an experimental area. Outside of this area as in parts of Farmington Canyon, it has become evident that some of the trenches were of inferior standards and that places where it was believed natural recovery would be effected without contour trenching should have been trenched. Some of these inadequately treated "spots" are continuing to produce flood runoff. This fact emphasizes the importance of both completeness and adequate design in systems of improvement measures.

Improved Watersheds Withstood Torrential Rains

Recovery of the test area was startling, particularly on sites which had lost but little soil. Good stands of grass soon came in on most of the formerly denuded flood-source areas. The shrubs, grasses, and herbs, relieved from the pressure of heavy grazing, not only increased in density but began to add litter to the soil surface, and the soil surface became less compact. There are some areas where so much soil had been lost that plant recovery has been slow, even though contour trenching has been effective in controlling runoff.

The contour-trenching program in general, however, has been remarkably effective. Over more than a decade it has stood up under the impact of recurring intense summer rains.

The effectiveness of the program was demonstrated even while improvement work was under way in Ford Canyon. On July 4, 1934, a rain of 0.47 inch fell on its headwaters. The upper portion of this basin embraces two sub-basins of about 200 acres each. Enough runoff was generated from about 75 acres of untreated flood-source areas in one of these sub-basins to produce a mud flow that carried boulders 9 feet long out of the canyon (fig. 10). However, contour-trenching operations had been completed in the other sub-basin a few days before the storm. Close examination revealed that this area produced no storm flow: all the rain had been trapped where it fell.

Later, two record-breaking rainstorms further tested the watershed improvement program. One of these rains, totaling 1.14 inches, occurred on July 10, 1936. During this storm, rain fell at the rate of 5.04 inches per hour for a 5-minute period. The other rain on August 19, 1945, totaled 1.06 inches. During this storm, rain fell, during the most intense 5-minute period, at a rate of 6.84 inches per hour (fig. 11). Both of these rates were greater than any recorded before in Utah.

When the storm of July 10, 1936, struck, practically all of the contour trenching and reseeding had been completed in Parrish, Barnard, Ford, Davis, and

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Figure 10.—**Boulders as much as 9 feet long were carried out of Ford Canyon as a result of less than one-half inch of rainfall on deteriorated flood-source areas.**

Steed Creek watersheds. No mud-rock floods issued from any of these treated drainage basins.

Mud-rock floods did occur, however, in four untreated sub-basins (Miller, Corduroy, Halfway, and Whipple) of Farmington Canyon. The flood in Miller Creek was so great that it washed out a stream-gaging station. The flood from Halfway drainage, according to flood marks left on the channel walls, was larger than the one in 1923 (fig. 12). Although some trenching has been done subsequently in these flooding sub-basins, three of them again flooded in 1947—clearly indicating the inadequacy of the treatment in those areas.

The absence of floods from the fully treated watersheds clearly indicated the value of an adequate improvement program. If no contour trenching had been done in these watersheds, enough runoff would have been turned loose to create major mud-rock floods. This was shown by the heavy discharge that occurred in a small sub-basin of Parrish Canyon where runoff was studied in detail. This sub-basin of 176 acres discharged a total of 28,234 cubic feet of runoff. Virtually all of this runoff originated on about 15 acres of barren roadways and campground areas. These poured off about 50 percent of the rain that fell on them.

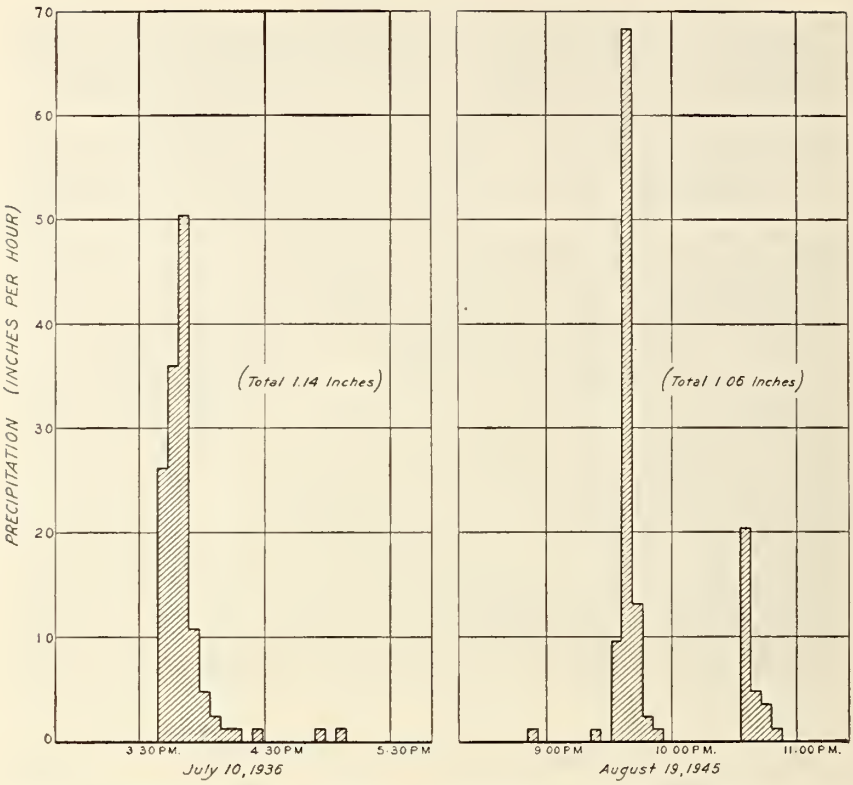

Figure 11.—Rainfall intensity-duration characteristics of two summer storms at Parrish Creek runoff plots.

On 80 acres of sparsely covered land that had been contour-trenched, rainfall was captured in the trenches (fig. 13). On another 81 acres of well-vegetated land, there was practically no overland flow; the plant cover and soil mantle absorbed and held virtually all the rain.

The still more intense rainfall that occurred on August 19, 1945, provided another severe test of the treatment program. During this storm, rain fell at rates one-third greater than during the record-breaking storm in 1936. Notwithstanding the unusually high rainfall rates attained, there were no mud-rock floods in either the treated watersheds or the untreated but managed Centerville Canyon. All of the creeks rose about a foot, but the maximum discharges averaged only about 10 cubic feet per second per square mile, and caused no damage.

On the same night, mud-rock floods, which attained discharges of more than 3,000 cubic feet per second per square mile, issued from recently burned watershed lands near Salt Lake City, about 15 miles to the south (*8*). This flood caused $345,000 damage to city property. Destructive mud-rock floods also

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Figure 12.—Halfway Creek channel scoured to bedrock by the mud-rock flood of July 10, 1936.

occurred in two other weakened watersheds—Bairs and Jump-Off—north of the Farmington-Centerville area.

Thus, while deteriorated watersheds nearby were producing destructive floods, the reconditioned watersheds were controlling runoff. With protection, the reconditioned areas should continue to provide flood control unless they are subjected to summer rains of much greater intensity than those measured in Utah over the past 70 years.

Runoff Relations on Reconditioned Watersheds

The intensively treated watersheds between Farmington and Centerville Canyons (Steed, Davis, Ford, Barnard, and Parrish) now present a far different aspect than they did after the floods of 1930. Most of the formerly depleted and eroding tracts are now capable of holding the soil and infiltrating rainfall from summer storms (fig. 14). It is becoming increasingly difficult to distinguish

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Figure 13.—Contour trenches in the head of Parrish Creek impound runoff from high intensity rainfall on July 10, 1936. This rain caused mud-rock floods in four untreated watersheds.

between the former "sore spots" and intermingled areas on which the plant cover and soil mantle had always been adequate for controlling runoff and for keeping the soil in place.

Torrential summer rains do not now result in destructive mud-rock floods. Practically all rain is absorbed by the soil mantle. The chief sources of storm flow now are merely the small areas occupied by roads, a few places where treatment was insufficient, and the stream channels. Much of the surface runoff yielded by the roadway and inadequately treated areas is dissipated and prevented from reaching the channels.

Now, whether storms are large or small, the streams rise only moderately. The storm flows are sustained for many hours. They no longer carry boulders. Stream flow has again been made usable, just as it has always been in the more wisely treated Centerville Canyon. There are no more business or traffic interruptions. Maintenance of irrigation diversions and canals has been lessened. Many of the flooded fields have been cleared of debris and new crops are coming in.

Why Continuous Watershed Management Is Necessary

All the evidence brought out in this publication clearly demonstrates that the mud-rock floods in the Farmington-Centerville area came from deteriorated

Figure 14.—Flood-source area in Ford Canyon. *A,* Deteriorated condition in 1930; *B,* same area in 1946, after recovery.

land. It also demonstrates that the damaged lands could be repaired by intensive treatment where enough soil remained to support a good plant cover.

However, restoration is a costly business. It cost at least $100,000 to install the emergency debris basins and floodways. It cost another $130,000 to contour-trench and seed the flood-source areas, $30,000 for truck trails to make the headwater areas accessible for treatment, and another $40,000 to acquire the land. These costs, totaling $300,000, represent an investment of $230 on each of the 1,300 acres of deteriorated land from which the floods came.

This, however, was only part of the cost of poor watershed management. When the $1,053,589 of damage sustained is added to the repair bill, the total cost per acre of flood source land becomes $1,040. This is about 200 times the value of the lands for grazing. All evidence points to the conclusion that range values and effective watershed protection could have been maintained had the lands been properly managed.

The people in Centerville escaped flood damage simply by arranging for moderate utilization of the watershed lands before they became deteriorated. In the remainder of the area, however, failure to act proved costly. Here unwise utilization of only 10 percent of the watershed lands brought on mud-rock floods. These floods, the damages, and the cost of repairs could have been avoided by proper watershed management, just as they had been in Centerville Canyon.

Effective watershed management must be continued in the Farmington-Centerville area to preserve the hard-gained freedom from floods. High-intensity storms are certain to occur in the future. Such rains, steep slopes, and a soil mantle that is highly susceptible to displacement if disturbed constitute a dangerous combination. They can cause more mud-rock floods unless adequate plant cover is maintained on the slopes to bind the soil and prevent excessive surface runoff. This calls for continuous intensive watershed management. Signs of watershed deterioration must be recognized early and corrective action taken promptly (*3*). If the plant and soil mantle should be damaged by any cause, even on small areas, repairs should be made immediately.

Improved management is needed on many other watersheds (*7*). Some communities have recognized this. People in the Wellsville mountain area of northern Utah have already acted. To stop overgrazing and burning, they placed flood-source lands in public control. They have also begun to repair damaged watershed areas. Several other communities, including North Ogden, Eden, and Mt. Pleasant, have started similar action.

Facts have been given about what happened to watersheds in only one portion of northern Utah. Management was effective there because it was possible to reestablish essentially the same capacity of the watershed mantle to handle rainfall that existed on the slopes prior to their deterioration. Specifically, this involved the control of only one or two inches of rainfall by a mantle that was capable of holding many inches of water. Such complete control of rainfall runoff is not possible in all parts of the West. In some places, floods and high rates of erosion are natural. For example, they are common in parts of southern California

because of prolonged rains and in parts of the Southwest because of a combination of sparse vegetation and shallow or impervious soil. Even in such areas as these, however, watershed management can reduce flood peaks and sediment loads to the extent that they have been increased by impairment of the plant cover. On all forest and range lands watershed management can prevent flood peaks and erosion rates from becoming greater than normal.

Every American community, that does not already have it, needs continuous protection against destructive floods and failure of the supply of usable water. Conditions on a watershed that indicate flood danger are not always readily apparent. Moreover, flood-control possibilities differ from place to place. Community leaders therefore should seek advice about local watershed conditions from men trained and experienced in the management of watershed lands.

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